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# DEVELOPMENT OF A CUTTER-CLEANER-LOADER SUGARCANE HARVESTER FOR USE IN LOUISIANA: A PROGRESS REPORT

By R. M. Ramp[1/]

This report describes recent progress in the development of a cutter-cleaner-loader type of sugarcane harvester designed for erect-growing canes. Early studies on this type of harvester were reported in 1956.[2/] The research program on sugarcane harvesting machinery was initiated at the request of the American Sugar Cane League in 1947.[3/] This organization provides both technical guidance and substantial financial assistance for research on sugarcane in cooperation with the U.S. Department of Agriculture.

In the continental United States, sugarcane for sugar is grown mainly in southern Louisiana and Florida. During the years 1956-60, from 531,000 to 616,000 tons of raw sugar per year were produced on 234,000 to 296,000 acres. Louisiana produced about 72 percent of the raw sugar on about 82 percent of the total acreage. The importance of this crop to Louisiana farmers, together with the weather and growing conditions peculiar to the area, demands specially designed harvesting equipment. The following description of Louisiana conditions explain the problems encountered in developing a cutter-cleaner-loader type of harvester that would be commercially acceptable for Louisiana.

The soils[4/] in the sugarcane area of Louisiana are largely of alluvial origin, formed from sediments washed from the watershed of the Mississippi River and its tributaries and deposited during flood stages of the river. The sandy materials were laid down next to the bayou banks while the fine clays were carried further from the bayou. The cultivable land built up by this process slopes from bayou bank to swamp and may vary in width from a few hundred feet to 3 or 4 miles.

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1/ Agricultural Engineer, Harvesting and Farm Processing Research Branch, Agricultural Engineering Research Division, U.S. Department of Agriculture.

2/ Ramp, R. M. Development of a Sugar-Cane Harvester Agr. Eng. 27(12):821-824. 1956.

3/ A nonprofit organization supported by producers and processors of sugarcane.

4/ O'Neal, A. M. and L. A. Hurst. The More Important Soils of the Sugarcane District of Louisiana and Their Physical Characteristics. International Soc. Sugar Cane Technol. Cong. Proc. 6:284-296. 1938.

Cane fields along the bayous are divided into cuts that vary from approximately 100 to 1,300 feet in length by 100 to 150 feet in width. The cuts are bordered on each side by field drainage ditches, which may be from 12 to 48 inches deep and from 30 to 48 inches wide. Headlands or roadways approximately 25 feet in width are provided at both ends of the cut for turning as well as for hauling cane from the field. The cane rows are parallel to the field ditches, and drainage within the cut is provided by quarter drains that extend from the side drainage ditches through the cane rows. These drains are dug to the bottom of the middles and are located at the low points within the cut to drain the entire cut. At least three quarter drains are normally used per cut with one drain at each end about 25 feet from the headland. Figure 1 illustrates the typical sugarcane field layout.

Figure 1. Typical sugarcane field layout.

A. Bayou
B. Field road
C. Drainage ditch
D. Direction of natural drainage
E. Field number
F. Cut letter
G. Cut acreage
H. Woods

Most of the soils have poor internal drainage and a high water table. This, along with the annual rainfall of 60 inches, makes it necessary to plant the cane in rows 12 to 16 inches in height. The rows are spaced approximately 6 feet apart to provide sufficient drained area for satisfactory production of the cane. Each cut normally contains from 16 to 24 rows.

Because of the annual freezes, sugarcane seldom matures completely, and the crop must be produced and harvested in 8 to 10 months. Most of the commercial varieties now grown are the erect type; however, they may be lodged by wind and rain. Recumbent varieties produce higher yields and may be widely grown if suitable harvesting equipment becomes available. The yield ranges from 15 to 40 tons of cane per acre with an average in Louisiana of 22 tons. Figures 2 and 3 illustrate erect and lodged cane. The USDA experimental sugarcane harvester described in this report was designed primarily to handle erect-growing varieties of sugarcane such as those most frequently grown in Louisiana.

Figure 2. Cut of erect sugarcane, variety C. P. 44-101, 1st stubble. Approximate yield, 30 tons per acre.

Figure 3. Sugarcane lodged by wind following heavy rains.

## Present Harvesting Practice

The present harvesting practice is a cutting-burning-loading operation. The cane stalks are cut top and bottom by machine and placed across the row ridge to form a heap or windrow (fig. 4). From three to six rows are placed in one heap row. The canes are left in the heap row one day or longer--depending on the weather--to dry the leaves sufficiently for burning (fig. 5). At

Figure 4. Sugarcane piled in heap rows after cutting top and bottom by present commercial sugarcane cutting machine.

Figure 5. Heap row of sugarcane after burning.

the start of the season, the leaves and tops are too green to burn satisfactorily while the cane is standing. After burning, the canes are loaded into carts by means of tractor-mounted loaders for transport to the processing factory.

Under normal conditions, one day or longer may elapse between cutting and milling. Rainfall during the harvesting period, however, averages 9.8 inches and frequently prevents the normal operation of burning. Thus, during rainy weather the cane is milled with a high percentage of trash in the form of leaves and mud. Delays in harvesting prolong the season, thus increasing the hazard of freeze loss. The quantity and kind of trash milled with the cane affects the amount of recoverable sugar. The combined effect of delayed milling and high percentage of trash results in losses to the producer and processor ranging from 8 to 22 pounds of sucrose per ton of cane. On this basis, fresh clean cane is worth $9.60 to $24 more per acre than cane most generally harvested by the present method.[5/]

5/ Arceneaux, George and Davidson, Lester. Some Effects of Trash in Cane on Milling Results. Sugar Bul. 22(18): 151-158, 1944.

Keller, Arthur C. and Schaffer, Francis C. The Effect of Cane Trash on The Milling Operation. La. State Univ. Engr. Expt. Sta. Bul. 25, p.43, 1951.

Keller, Arthur G. Fresh, Clean Cane. La. State Univ. Engr. Expt. Sta. Bul. 28, p.40, 1952.

Balch, R. T. and Broeg, C. B. The Sugar Cane Trash Problem from a Chemical Standpoint. Sugar 43(12) 1948.

The main disadvantage of present harvesting practices is that satisfactory operations depend on sufficient clear weather for burning the cane leaves. In good weather the canes can be burned satisfactorily and loss due to delayed milling can be kept to a minimum. However, in rainy weather, it is necessary to mill cane with trash rather than hold up delivery until the cane can be burned, in order to maintain harvesting schedules. Appreciable loss of recoverable sugar and reduction in milling capacity may result.

### Advantages and Disadvantages of the USDA Experimental Cutter-Cleaner-Loader Type of Sugarcane Harvester

The USDA cutter-cleaner-loader type of sugarcane harvester offers the following advantages as compared with the conventional harvester:

1. Fresh, clean cane can be delivered to the mill during all types of weather.
2. The grinding rate at the mill is increased when fresh, clean cane is ground.
3. Harvesting can be quickly shifted from one field to another depending on weather conditions, sucrose tests, or other factors.
4. Cane trash returned to the soil instead of being burned increases cane and sugar yields.[6]
5. The experimental harvester is better adapted to custom harvesting and hauling.
6. The experimental harvester is adapted for around-the-clock operations for the most efficient utilization of equipment.
7. Field rutting and physical damage to the soil is reduced by less travel in the field.
8. Less labor and supervision are required in the combined operation with the experimental harvester as compared with several operations (cutting, burning, and loading) in the conventional method.
9. Special equipment to open the first row in each cut of cane is not needed because a rear-loading machine opens its way.
10. Elimination of the loader may reduce the overall investment in equipment.
11. Neater bundles and less handling reduces the droppage of canes and breakage of bundles in trucks, fields, and factory derricks.
12. Procurement of planting cane is facilitated.

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6/ Hebert, Leo P. and L. G. Davidson. Effect of Cane Trash, Legumes, and Bagasse on Cane and Sugar Yield and on the Organic Matter Content of Louisiana Sugarcane Soils. International Society Sugar Cane Technol. Proc. pp. 565-579, 1960.

Disadvantages of the USDA experimental cutter-cleaner-loader type of sugarcane harvester are as follows:

1. The harvesting method does not provide a backlog of sugarcane in the field for delivery in case of a harvester breakdown.
2. Scrapping behind a cutter-cleaner-loader type of harvester is difficult because of leaves and trash mixed with cane stalks.
3. The change to cutter-cleaner-loader type harvesting necessitates the outlay of new capital and will probably be gradual. New once-over cane harvesters will be purchased to replace worn out conventional equipment.
4. A cutter-cleaner-loader type of harvester probably would cut a little less cane per hour than a conventional harvester. This amount, however, is clean loaded cane as compared with cut, but unburned, cane under the present method.
5. A harvester that pulls its own cane wagon requires more horsepower in the unit.
6. The harvesting and hauling operations must be coordinated to minimize time loss.

Specifications of USDA Experimental Sugarcane Harvester

| | |
|---|---|
| Type | Self-propelled |
| Engine | 95 hp. |
| Type | Gasoline |
| Speed | 2,200 r.p.m. |
| Weight | 18,600 pounds |
| Tires, front, steering, number | 2 |
| size | 9:00 x 24 |
| ply and type | 8, multiple rib, implement |
| inflation | 32 p.s.i. |
| Tires, rear, number | 2 |
| size | 18:00 x 26 |
| ply and type | 8, rice and cane special |
| inflation | 16 p.s.i. |
| Steering, type | Hydraulic |
| Brakes, drive wheel, size & type | 11 x 8, disk |
| Wheel base | 100 inches |
| Front tire tread | 72 inches |
| Rear tire tread | 72 inches |
| Width, overall | 96 inches |
| Height, overall | 141 inches |
| Length, overall | 40 feet |
| Length, overall, including wagon | 45 feet |
| Turning radius, tire, outside | 18 feet |
| Row clearance | 24 inches |
| Speeds, forward | 6 (1.07, 1.49, 1.99, 2.77, 4.83, and 6.73 m.p.h.) |

| | |
|---|---|
| Speeds, reverse | 2 (.80 and 1.11 m.p.h.) |
| Gatherers, speed range | 40 to 614 f.p.m. |
| angle range | 31 to 48 degrees |
| Topper, hydraulic pump, speed | 1,100 r.p.m. |
| hydraulic motor, speed | 943 r.p.m. |
| diameter | 20 inches |
| speed | 943 r.p.m., 4,900 f.p.m. |
| height range | 60 to 108 inches |
| Bottom cutters, number | 2 |
| diameter | 23 inches |
| speed | 438 r.p.m., 2,753 f.p.m. |
| height range | 9 to 20 inches |
| Elevating conveyor speeds | 4(169, 238, 307, & 442 f.p.m.) |
| Lower stripper speed | 660 r.p.m. |
| Upper stripper speed | 643 r.p.m. |
| Loader speeds | 4(171, 240, 310, & 447 f.p.m.) |
| Wagon winch motor speed | 1,257 r.p.m. |

## Specifications of Special Sugarcane Wagon

| | |
|---|---|
| Type | 4-wheel |
| Front tire size | 8:25 x 20 |
| ply | 10 |
| inflation | 70 p.s.i. |
| Rear tire size | 14:00 x 24 |
| ply | 8 |
| inflation | 25 p.s.i. |
| Weight | 5,500 pounds |
| Capacity | 6 tons |

## Description of Harvesting Operations and Harvester Components

The cutter-cleaner-loader experimental sugarcane harvester is a self-propelled machine designed to operate astraddle the row being harvested. Cuts are opened without making down rows or prior cutting (fig. 6). The harvester is designed to pull a trailing wagon having a capacity of 6 tons of cane in wet fields. Two men are required to operate the harvester. The front operator controls the steering and the height of gathering, topping, and bottom cutting. The rear operator controls the loading and wagon transfer operations. Two helpers are required for placing and tying cane slings in the wagons and changing wagons. The operation of the sugarcane harvester is illustrated by the schematic diagram in figure 7.

### Chassis

The arch-type steering front axle assembly has a ground clearance of 134 inches to permit the topped canes to pass under the axle. Hydraulic power

Figure 6. Rear view of USDA Experimental Sugarcane Harvester opening a field.

steering (fig. 8) is used to facilitate turning on narrow headlands. The propelling rear axle assembly (fig. 9) contains drop housing final drives to provide 24 inches of ground clearance.

Heavy duty disk brakes are employed on each rear wheel to assist in making short turns in muddy fields. The chassis is designed so that the cane passes beneath the front axle arch and over the propelling axle.

Gatherers

The primary function of the gatherer assembly is to pick up and gather the canes into a vertical pattern that permits proper topping and conveying through the harvester. A vertical lift chain (fig. 10) picks up the canes that are lodged between the rows and conveys them into the main gathering chains (fig. 11). The variable speed drive of the gatherer assembly enables the operator to adjust the speed of the gatherer chains to the forward speed of the harvester and to the cane pattern. Adjustments are provided in the gatherer thrust arms to vary the angle of the gatherer from $31^{\circ}$ to $48^{\circ}$ with respect to the ground. The smaller angle position is used to gradually

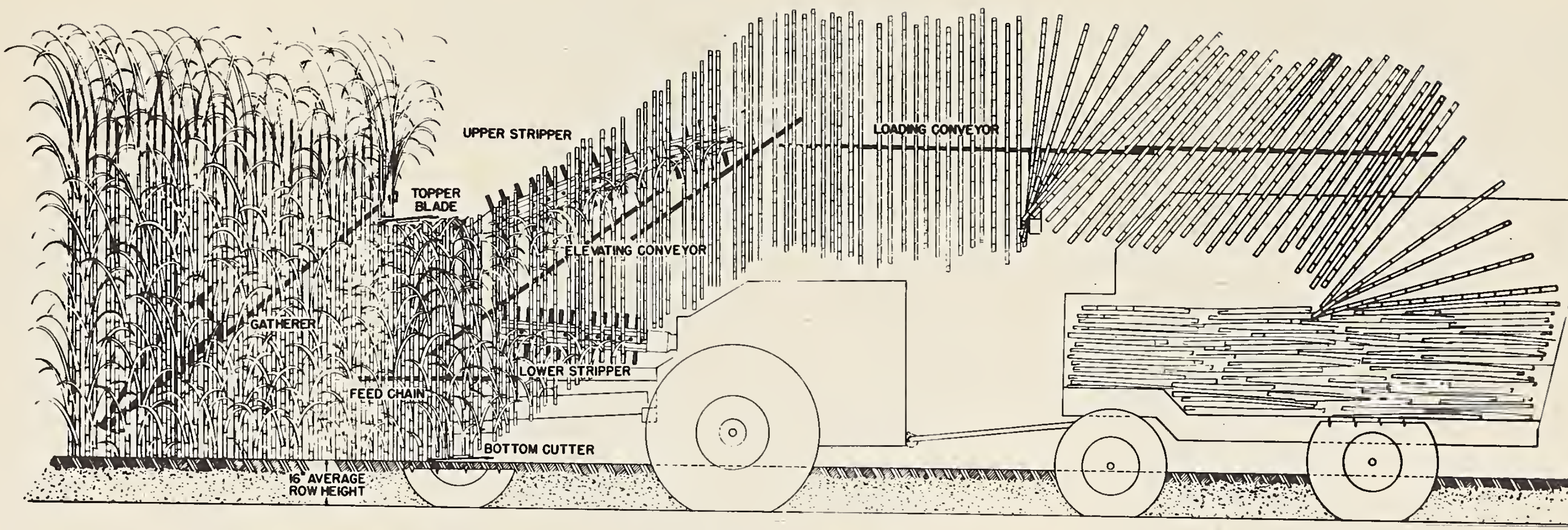



Figure 7. Schematic diagram illustrating the flow of sugarcane through the USDA experimental sugarcane harvester.

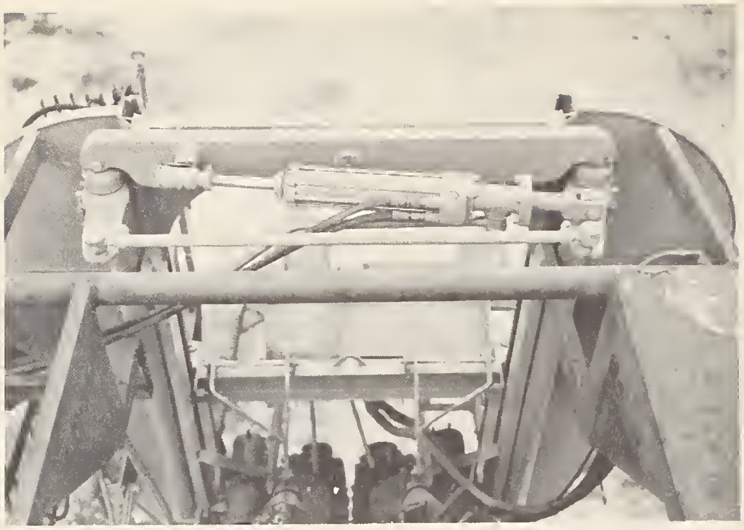


Figure 8. Hydraulic steering booster.

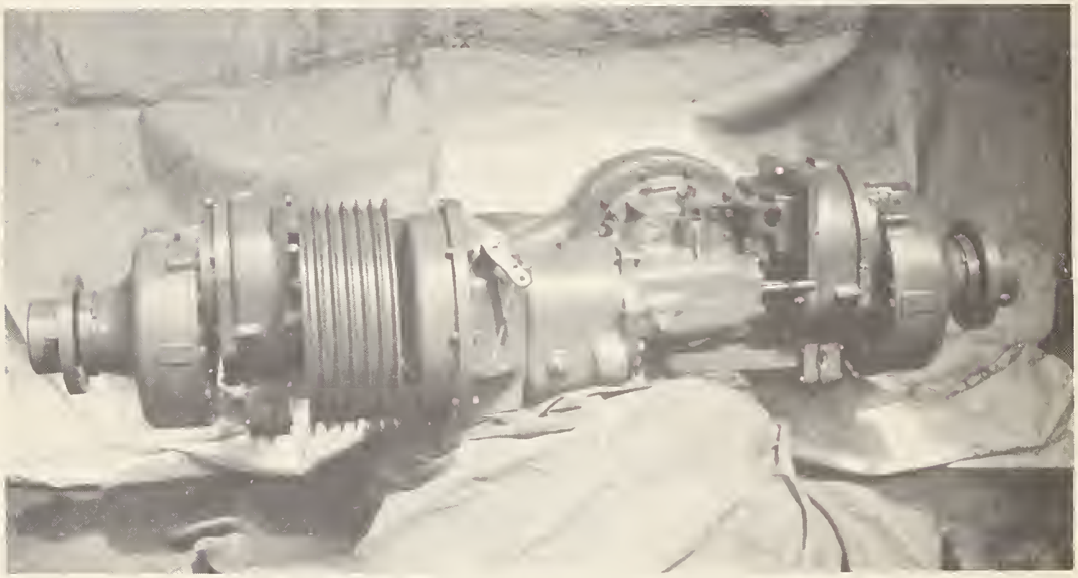


Figure 9. Special rear axle assembly. Ground speed and reduction based on 1,237 r.p.m. input and 18:00 x 26 rice and cane tires.

| Gear | Reduction | Ground speed, m.p.h. |
|---|---|---|
| First | 202 - 1 | 1.07 |
| Second | 145 - 1 | 1.49 |
| Third | 109 - 1 | 1.99 |
| Fourth | 78 - 1 | 2.77 |
| Fifth | 45 - 1 | 4.83 |
| Sixth | 32 - 1 | 6.73 |
| Reverse, low | 270 - 1 | .80 |
| Reverse, high | 194 - 1 | 1.11 |

separate canes that may be slightly lodged, whereas the greater angle is used for canes in an erect position.

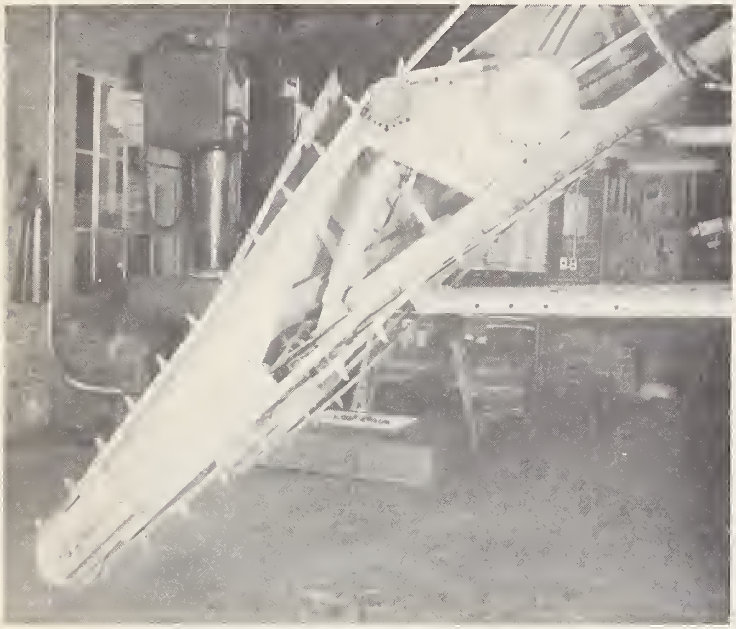


Figure 10. Gatherer vertical lift chain assembly.

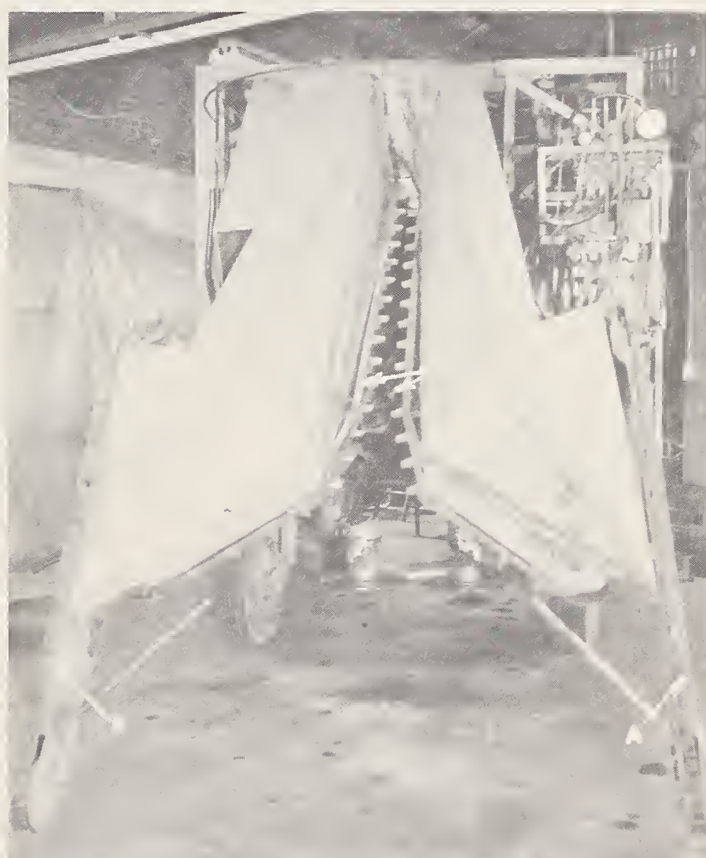


Figure 11. Gatherer assembly.

A. Vertical lift chain
B. Main gatherer chain

## Topper

The topper and gatherer assemblies are combined so that the gatherer chains act as feeders to the topper blade, as shown in figure 12. The topper blade consists of a disk, 16 inches in diameter, equipped with four heavy-duty serrated mower sections and is driven at 943 r.p.m. by a 60-pound inch per 100 p.s.i. hydraulic motor.

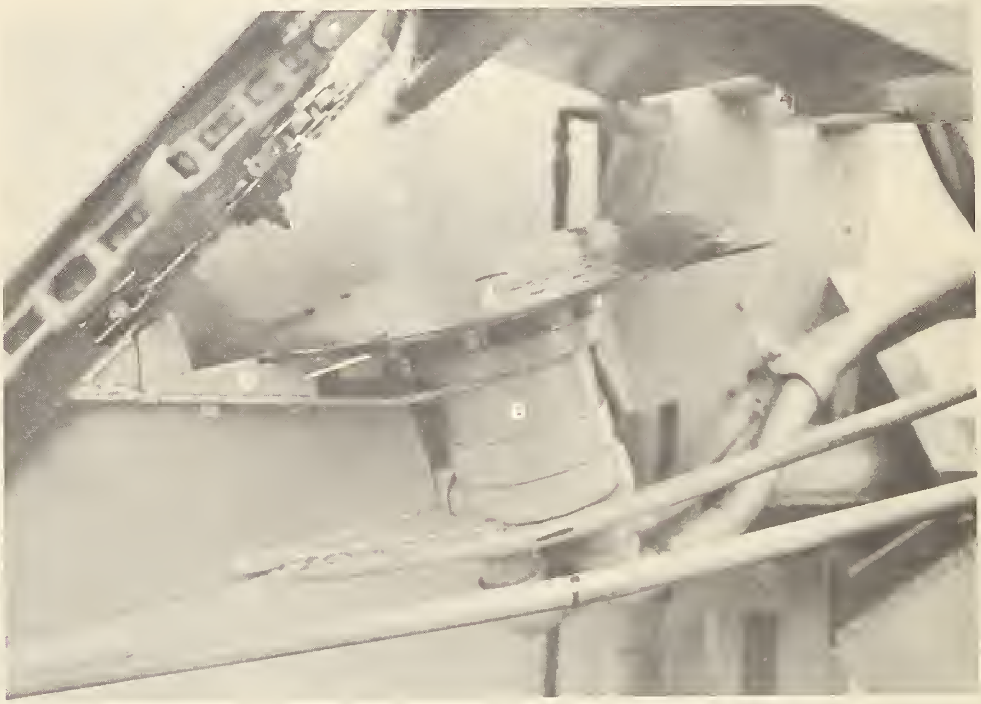


Figure 12. Topper assembly.

A. Topper blade
B. Topper motor
C. Topper feeder chain
D. Topper shear plate

The canes are conveyed into the topper blade by the right-hand gatherer chain and the tops are severed by the shearing action between the mower sections and the shear plate. The severed tops are carried into the topper chute by the gatherer chain and released directly ahead of the right front wheel. The front edge of the topper blade is tilted down approximately $5^{\circ}$ from the horizontal to provide cane clearance and to minimize recutting. The height of topping is hydraulically controlled and can be varied as desired from 60 to 108 inches.

## Bottom cutters

Figure 13 illustrates the general arrangement of the bottom cutter assembly. The bottom cutters consist of two disks, 19 inches in diameter, each equipped with 10 heavy duty serrated mower sections equally spaced on the periphery and projecting 2 inches beyond the disk. The two disks are timed so that the cutting sections are staggered. The mower sections overlap 2 inches

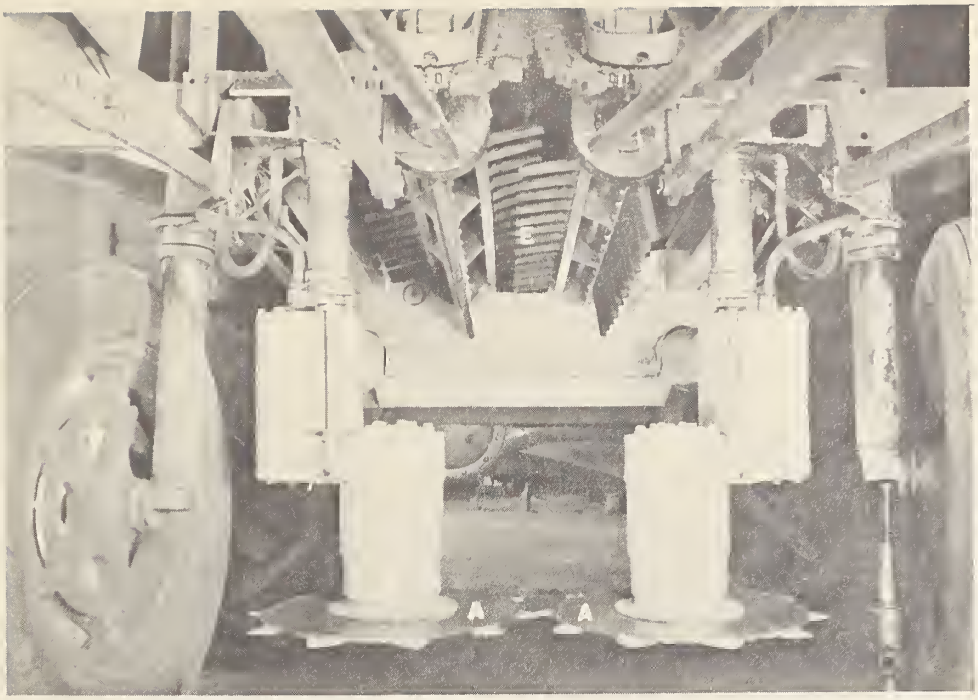



Figure 13. Bottom cutter assembly.
A. Cutter blade C. Torsion member
B. Height control cylinder D. Front wheels and spindles
E. Bottom view of lower stripper

to cut all the canes but at the same time provide sufficient clearance for the passage of tramp iron, bricks, and similar material, with minimum damage. The cutters rotate inwardly in opposite directions at 438 r.p.m. The cutters are fastened together with a torsion member and hydraulic equalizer for maintaining both cutters in the same horizontal plane. The height of the bottom cutters can be varied as desired from 9 to 20 inches by hydraulic cylinders connected through a hydraulic equalizer. The cutters are normally operated at or slightly below ground surface of the top of the cane row, and the front edges are tilted down approximately 2$^{\circ}$ to reduce the friction between the cutter blade and the top of the cane row. Eight hundred to 1,200 tons of sugarcane can be cut between sharpening. Daily inspection is necessary to repair damage to the sections caused by tramp iron, bricks, and similar material.

Elevator feeder

The primary function of the elevator feeder chain is to reduce droppage by guiding the canes between the gatherer and the elevating conveyor during the topping and bottom cutting operations. The chain lugs maintain the canes in a near vertical position but allow vertical movement. The front end of the feeder assembly is attached to the gatherer assembly and moves vertically with it. The rear support is mounted near the elevator to provide a positive transfer of the canes to the elevating conveyor. A variable speed drive

enables the operator to adjust the speed of the feed chains to the forward speed of the harvester.

Elevating conveyor

As the canes leave the top and bottom cutters they are transferred while in a vertical position to the elevating conveyors where they are gripped approximately 40 to 48 inches above the bottom cut. The elevating conveyors raise the canes at an angle of approximately $34^{\circ}$ with respect to the ground line as they are conveyed through the strippers to the loading unit (fig. 14). Adjustments are provided at the front support for varying the height of gripping according to the length of the canes. The conveyor consists of two chains equipped with rubber blocks or stickers for gripping the canes and is operated at a horizontal component speed slightly above the harvester ground speed. A transmission is provided for adjusting the conveyor speed to the harvester ground speed to maintain a constant cane pattern density. A step is provided in the conveyor approximately two-thirds of the distance from the front to permit the canes to be regripped for stripping the unstripped gripping zone. The two sections overlap each other approximately 10 inches to minimize the dropping of cane.

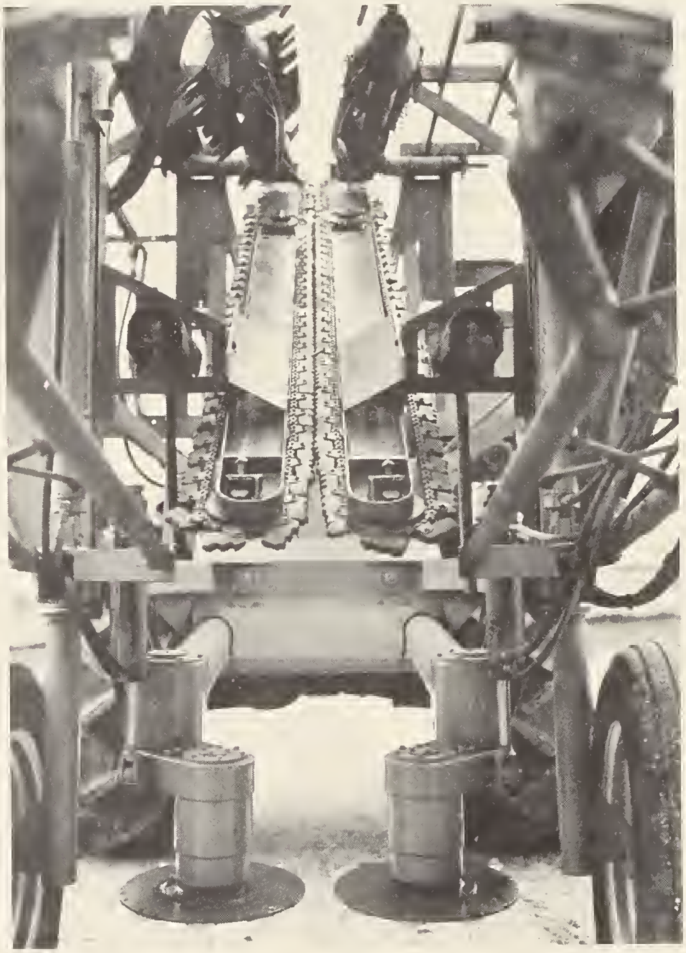


Figure 14. Front view of elevating conveyor.

Lower strippers

The lower stripping assembly consists of two cylinders on which stripping fingers are mounted for removing the cane leaves. The cylinders are located beneath the front section of the elevating conveyor and are rotated so as to comb downward as the canes are moved rearward and upward between the cylinders. Horizontal adjustments are provided to vary the amount of contact between the stripping fingers and the canes. The arrangement of the cylinder spacing is illustrated in figure 15. The on-center distance is equivalent to the

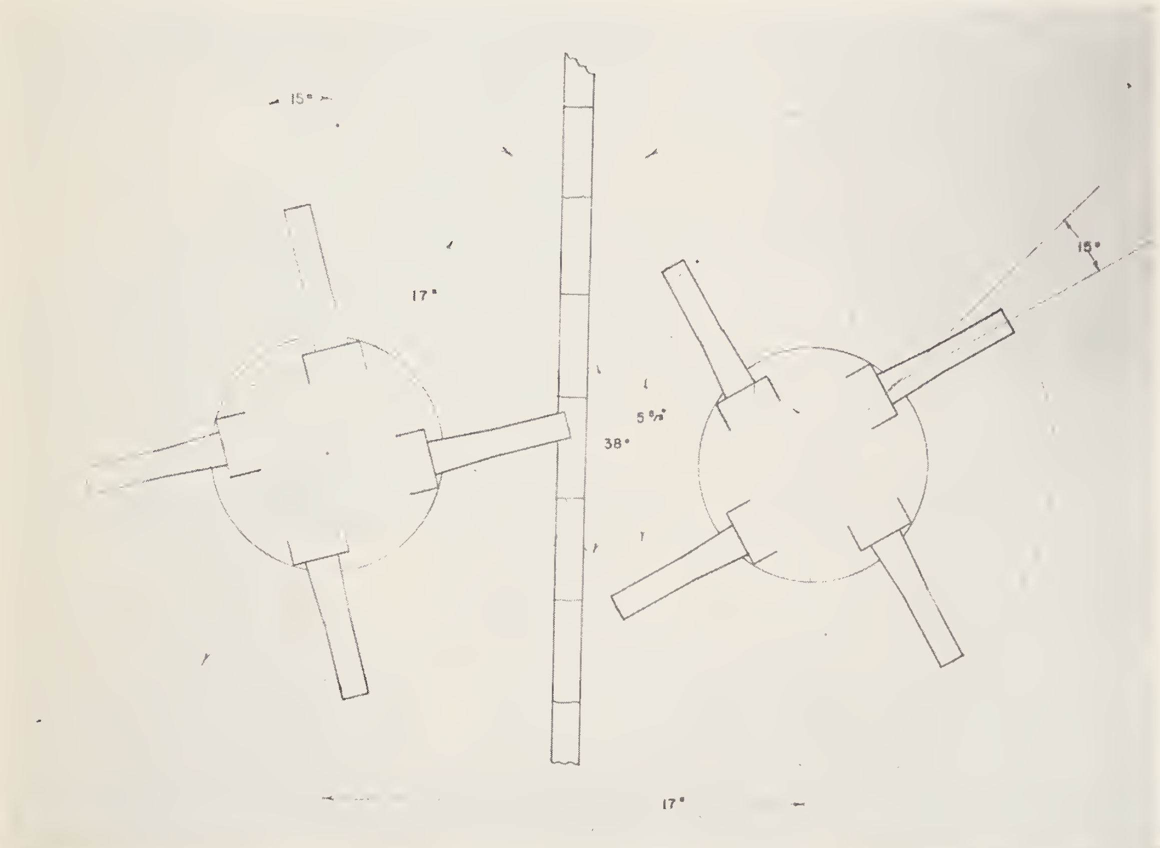



Figure 15. End view of lower stripper illustrating arc of contact and backward mounting of the rubber stripping fingers.

effective diameter of the stripping cylinders, thus providing no clearance between the ends of the stripping fingers. The two cylinders are timed so that the stripping fingers on opposite cylinders are staggered. A peripheral speed of approximately 2,937 f.p.m. is normally required to minimize wrapping and at the same time effectively remove the cane leaves. Lower speeds can sometimes be used without reducing effectiveness; however, in wet and weedy fields objectionable wrapping is frequently encountered. Mounting the stripping fingers at a backward angle of 15° with respect to the cylinder radius (fig. 15) reduces wrapping of trash on the fingers without affecting stripping efficiency.

## Upper strippers

The upper stripping assembly is located above the elevating conveyor and consists of two cylinders equipped with stripping fingers for removing leaves from the cane in the area not cleaned by the lower stripper. The front end of the cylinders is attached to the topper assembly so that the top ends of the canes enter the end of the stripping cylinders at or above the center line between the cylinders. The cylinders are rotated at a peripheral speed of approximately 2,861 f.p.m. and comb downward on the canes as the canes are moved rearward and upward between the cylinders. The horizontal clearance or overlap between the cylinders can be adjusted to compensate for the brittleness and quantity of leaves to be removed from the top ends of the canes. The cylinder spacing is approximately 1 inch greater than the effective diameter of the stripping cylinders. As with the lower strippers, installation of the stripping fingers at a backward angle of 15$^{\circ}$ reduces the wrapping of cane leaves.

## Loader

The main function of the loader unit is to convey the cleaned canes into the wagon attached to the rear of the harvester. This unit consists of a loader arm equipped with a sticker chain and rub rail. The canes are transferred to the loader from the elevating conveyor in approximately a vertical position and are carried in the loader arm in about the same relative position.

The rub rail at the front section (approximately 93 inches long) is maintained in a fixed position. The rub rail on the rear section is pivoted and controlled by a hydraulic cylinder, which makes it possible for the operator to vary its position as desired. When the rub rail is closed against the carrier chain, the canes are carried to the end of the arm before they are released into the wagon (fig. 16). By varying the position of the rub rail, the point of cane discharge into the wagon can be adjusted from the front to the rear of the wagon. Figure 17 shows the loader arm in operation. The horizontal position of the canes in the wagon is controlled by swinging the entire loader assembly about the harvester vertical support. The rear discharge point has a horizontal travel from left to right of approximately 144 inches, which enables the operator to place the canes at any desired position from side to side in the wagon. In addition to the horizontal movement, the loader arm is mounted on a horizontal pivot at its rear support so that the operator is able to lower the arm into the wagon for proper placement of the canes when starting a load and to maintain the proper loader arm height as the wagon is filled. The loader unit places the canes lengthwise in the wagon in such a manner as to tie the entire load together for unloading the cane in one bundle.

The loader unit is driven through a transmission for varying the loader conveyor speed to the forward gear used. The loader chain is normally driven at approximately 150 percent of ground speed while thinning the cane pattern and for placing the canes in the wagon.

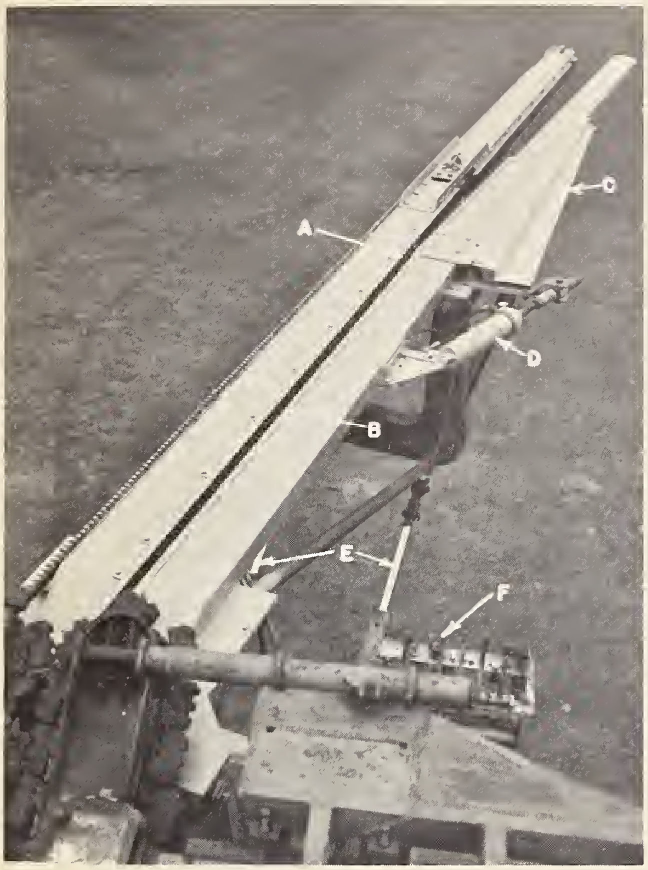



Figure 16. Aerial view of loader arm assembly.

A. Carrier chain
B. Front rub rail
C. Pivoted arm rub rail
D. Pivoted arm control cylinder
E. Vertical hydraulic control cylinders
F. Loader hydraulic controls

Figure 17. Loader arm in operation.

Wagon hitch

A truck winch for pulling the trailing wagon is mounted on the rear of the harvester. This winch is driven by a hydraulic motor controlled by the loader operator who can play-off or take-up cable as required. To transfer from a loaded to an empty wagon, cable is played-off until there is sufficient slack to disconnect the cable and attach it to the empty wagon (fig. 18).

Figure 18. Wagon transfer: Loaded wagon is dropped and spotted wagon is picked up.

The winch is then reversed and the empty wagon is brought into position while the harvester is in motion. To facilitate making transfers at the end of the row, the play-off rate is equivalent to the forward speed of the harvester. Thus, it is possible to stop the motion of the wagon while turning the harvester at the end of the row.

Wagon transfers can be made either at the end of the row or in the row. In addition, the winch can be used to assist in loading lodged or crooked canes by permitting the wagon to drop back when cane tends to heap or build up at one spot in the wagon.

Hydraulic systems

The hydraulics of the experimental sugarcane harvester consist of four systems supplied from one reservoir. The pumps for each system are driven independently of the propelling and harvesting clutches. The bottom cutters are provided with dual controls so either operator can adjust the height. Details of the hydraulic systems are illustrated in figure 19 along with the specifications of the main components.

Wagons

While the cane wagon is not a component part of the experimental sugarcane harvester, it is essential for efficient harvesting operations. In the present harvesting method, the conventional Louisiana sugarcane carts

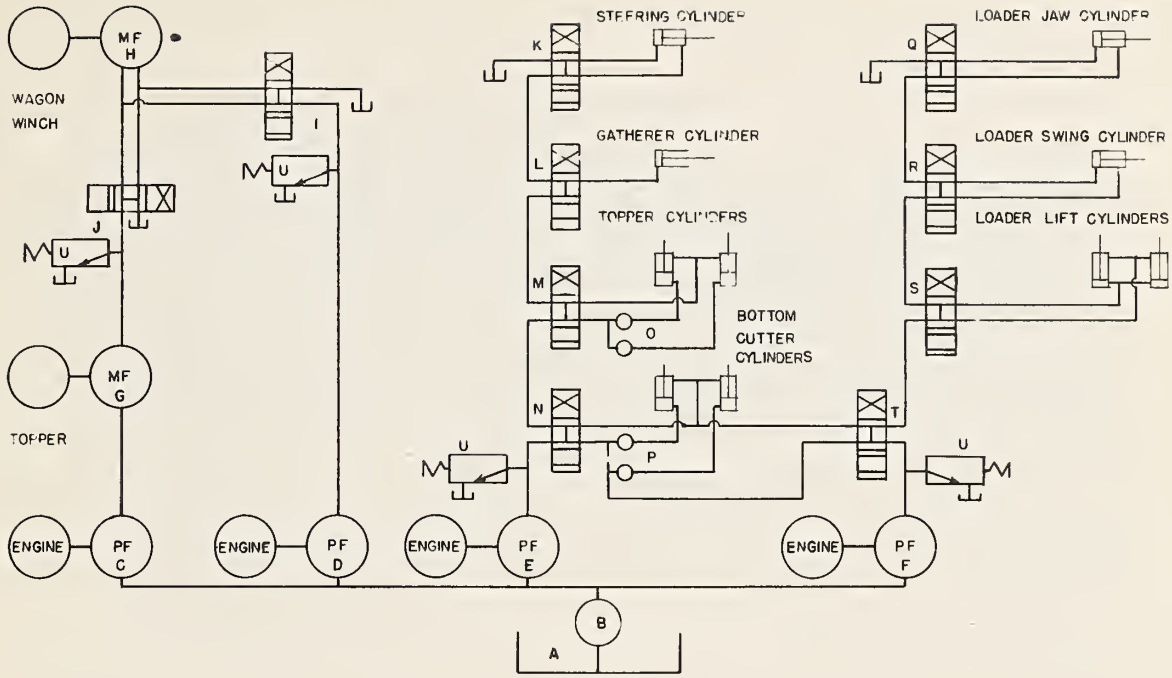



Figure 19. Hydraulic systems of the USDA experimental sugarcane harvester.
A. Reservoir, 35 gallons
B. Filter, 100 mesh
C. Pump, topper, 15 g.p.m., 1000 p.s.i. max.
D. Pump, winch booster, 5.3 g.p.m. at 2000 r.p.m., 2000 p.s.i. max.
E. Pump, front controls, 5 g.p.m. at 2000 r.p.m., 1500 p.s.i. max.
F. Pump, loader controls, 5 g.p.m. at 2000 r.p.m., 1500 p.s.i. max.
G. Motor, topper, 60 pound inch/100 p.s.i.
H. Motor, winch, 40 pound inch/100 p.s.i.
I. Control, winch booster
J. Control, winch
K. Control, steering booster
L. Control, gatherer variable speed
M. Contact, topper height
N. Control, bottom cutter height
O. Equalizer, topper height cylinders
P. Equalizer, bottom cutter cylinders
Q. Control, loader jaw cylinder
R. Control, loader swing cylinder
S. Control, loader lift cylinder
T. Control, bottom cutter height
U. Relief valve

(fig. 20) are used in tandem. However, in muddy fields it is frequently necessary to drop off the rear cart. Once attached, the cart normally remains with the cane tractor for the entire season except for flat tires or breakdowns. Such an arrangement can be used only for side loading.

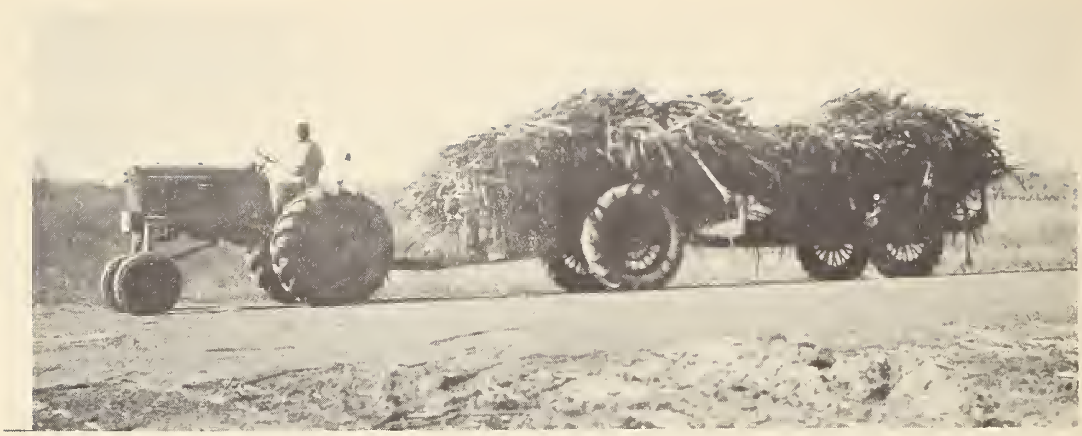


Figure 20. Conventional Louisiana sugarcane carts.

With the experimental harvester, the conventional cane cart can be loaded directly only when attached behind the harvester, but it is unstable, especially when loaded. It is difficult to transfer the loaded cart from the harvester to the transport tractor. Because of the problems encountered with these carts, special four-wheel, 6-ton capacity wagons were developed to provide stable units that could be easily attached or detached from the harvester and tractors. The initial cost of the special wagon led to later work on adapting the conventional cart to four-wheel wagons by means of a gooseneck assembly. Figures 21 and 22 illustrate the special 6-ton wagon

Figure 21. Special 6-ton capacity wagon.

and the converted conventional Louisiana cart. The capacity of the converted wagon is 3 to 4 tons and could be increased to approximately 6 tons by flaring the bed. All the wagons are equipped with drop tongues and can be easily hooked onto and unhooked from the tractor or harvester.

The wagons can be made up into trains (fig. 23) to obtain the maximum capacity with the transport tractors. With the cutting, cleaning, and

Figure 22. Converted Louisiana cane cart.

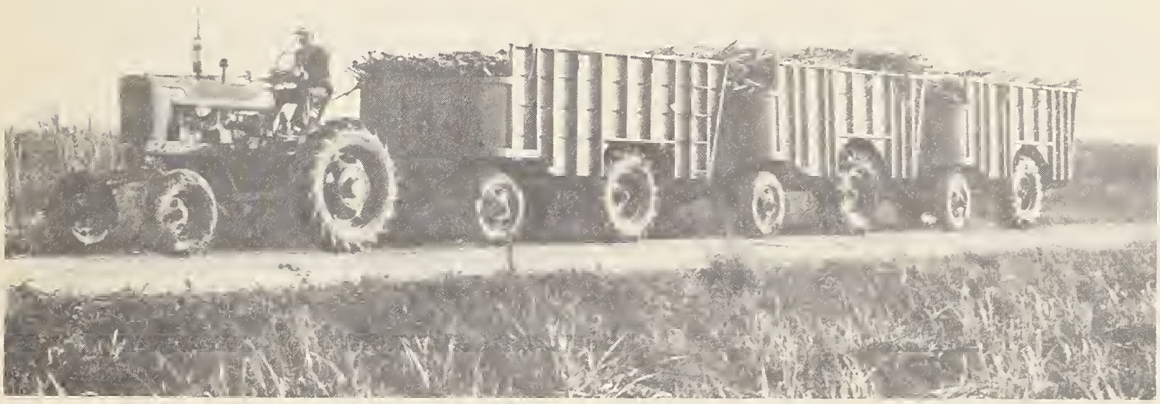


Figure 23. Cane wagons operated in trains.

loading system, the harvesting and hauling operations function independently. Short delays in the harvesting operations do not interfere with hauling, and, conversely, hauling delays do not stop the harvester. With the conventional method of harvesting, the stockpile of cane on the ground permits the hauling operations to continue. Major delays in either system will affect the daily capacity. The number of wagons and transport tractors required depends on the length of haul and the turn-about time needed for each unit. Under normal conditions, from six to eight wagons and three tractors are required for continuous operation of the experimental harvester.

## Harvesting Operations

After the chain slings have been placed, the wagon is pulled into place behind the harvester with the hydraulic operated wagon winch. The top and

bottom cutters are set at the approximate desired height before the row is entered, and the harvester clutch is engaged. As soon as the harvester is in alinement with the row, the engine is brought to full speed and the bottom and topper cutters are further adjusted to meet the row specifications. The gatherer adjustments are made in the row. Turns can be made either to the right or left in opening a cut or field, but it is advisable to avoid point rows or any rows that may involve operating hazards such as deep quarter drains, stumps, guy wires, and utility poles. These rows can be harvested safely after opening when there is better visibility and more maneuvering area. After a little experience, the operations can be planned to eliminate short turns and to minimize travel time on the headland.

## Performance

The performance of the sugarcane harvester is evaluated on the following factors: capacity, trash, stripper finger life, and ground loss.

### Capacity

The capacity of the experimental sugarcane harvester depends on field conditions and the inherent capacity of the harvester components. Since the ground speed remains practically constant, in fields of erect cane the yield per acre has a direct effect on capacity. In muddy fields or lodged cane, it may be necessary to reduce the forward speed. Because of freeze hazard, it is frequently necessary to continue harvesting operations during wet and rainy periods.

Continuous operation of the experimental sugarcane harvester is limited by the 95 hp. engine to a maximum continuous ground speed of 1.9 m.p.h. even though tests have frequently indicated that field conditions would allow higher speeds. Field layouts that require frequent turns reduce the capacity of the harvester. Under normal conditions, capacity ranges from 20 to 25 tons per hour at a ground speed of 1.9 m.p.h. Depending on field and cane conditions the rate of harvesting while going down the row has varied from 600 to 1,200 pounds per minute for cane yielding 20 to 30 tons per acre. The maximum daily capacity during 1959, 1960, and 1961 ranged from 110 to 167 tons per day while the quantity of cane harvested ranged from 1,718 to 2,459 tons per season. Close coordination between hauling and harvesting operations was required to obtain the maximum daily capacity. A delay of 5 minutes is equivalent to a loss of 1-1/2 to 3 tons of cane capacity. With proper coordination, the time lost between wagons should not be greater than one minute, and frequently the transfer can be made in 30 seconds.

### Trash

Trash consists mainly of leaves and tops, but includes also soil, weeds, or similar material that is taken to the mill with the cane. The quantity of soil is negligible in the direct method of harvesting. In the field tests, trash determinations were made by sampling each fifth load, and the daily percentage of trash was computed from these samples. At the start of the harvesting season in Louisiana, trash constitutes approximately 33 percent of the total weight of unharvested cane. By the end of the season, approaching maturity and freezes reduce the total trash to approximately 25 percent

of the total cane weight. The quantity and distribution of trash on the stalks depend on the variety. For example, N. Co. 310 has a higher proportion of tops (with negligible sucrose content) and leaves than does C.P. 44-101. The tops normally represent approximately 60 percent of the total trash.

Field results for the 1959, 1960, and 1961 seasons with the experimental sugarcane harvester and the conventional harvesting method are summarized in table 1. The experimental sugarcane harvester has consistently supplied cane to the mill with less trash than has the conventional method, and the variation in the amount of trash is not affected as much by weather conditions as with the conventional method.

The topper unit is an integral part of the gathering assembly of the experimental harvester. The height of topping can be varied to meet field conditions; however, no effort is made to adjust the topper to individual stalks. They are average topped, which means that some are topped too high and include trash while others are topped too low and millable cane is lost. Proper topping is essential since the tops make up such a high percentage of the total weight as related to the weight of the millable cane. In addition the tops contain considerable nonsucrose solids, which interfere with the processing operations. At the start of the harvesting season the canes are immature and it is frequently necessary to top low to obtain standard sucrose (12 percent). As the season advances, maturing of the canes and freezes reduce the quantity of green tops and leaves and in turn permit higher topping. The operator adjusts the height of the topper to harvest at the desired stalk height. While the varieties and field conditions have a direct effect on the quantity of trash, the effectiveness of the detrashing components of the experimental harvester depends in large part on ground and stripper speeds.

Table 1. Field test data summary

| Items compared | Harvesting season | | |
|---|---|---|---|
| | Oct. 19-Dec. 20, 1959 | Oct. 25-Dec. 30, 1960 | Oct. 17, 1961-Jan. 8, 1962 |
| | Experimental sugarcane harvester | | |
| Yield -- tons | 2,459 | 1,718 | 2,383 |
| Trash: | | | |
| Average -- percent | 5.02 | 6.65 | 5.55 |
| Minimum -- percent | 3.20 | 3.85 | 3.47 |
| Maximum -- percent | 13.04 | 12.80 | 8.55 |
| | Conventional harvesting method | | |
| Trash: | | | |
| Average -- percent | 6.29 | 8.04 | 7.16 |
| Minimum -- percent | 2.89 | 4.08 | 3.24 |
| Maximum -- percent | 14.66 | 15.00 | 17.48 |
| Decrease in trash with experimental harvester -- percent | 1.27 | 1.39 | 1.61 |

A test was conducted to determine the effect of ground speed upon percent trash on variety C.P. 44-101. Each speed was replicated five times, one row per replication, for which five trash samples were taken per row. The upper and lower stripping cylinder speeds were 643 and 660 r.p.m. Ground speeds of 1.54, 1.94, and 2.72 m.p.h. were used. The five trash samples were combined to provide one average percent trash per replication. The results are given below:

Effect of ground speed upon percent trash.
USDA experimental sugarcane harvester, 1958.

| Speed (mph) | Trash (Average percent) |
|---|---|
| 1.54 | 2.84 |
| 1.94 | 3.22 |
| 2.72 | 3.85 |

LSD at 5 percent level = 0.54, 1 percent level = .79.

These results showed a significant increase in trash for an increase in speed from 1.94 to 2.72 m.p.h., however the increase in trash from 1.54 to 1.94 m.p.h. was not significant. The increase in trash was significant at 1 percent level for an increase in speed from 1.54 to 2.72 m.p.h. These results are illustrated graphically by figure 24.

Three tests were conducted at a harvesting speed of 1.94 m.p.h. to determine the effect of the upper stripping cylinder speed upon percent trash. The test plot consisted of two rows per cylinder speed from which five trash samples were taken per row, making a total of ten trash samples per cylinder speed.

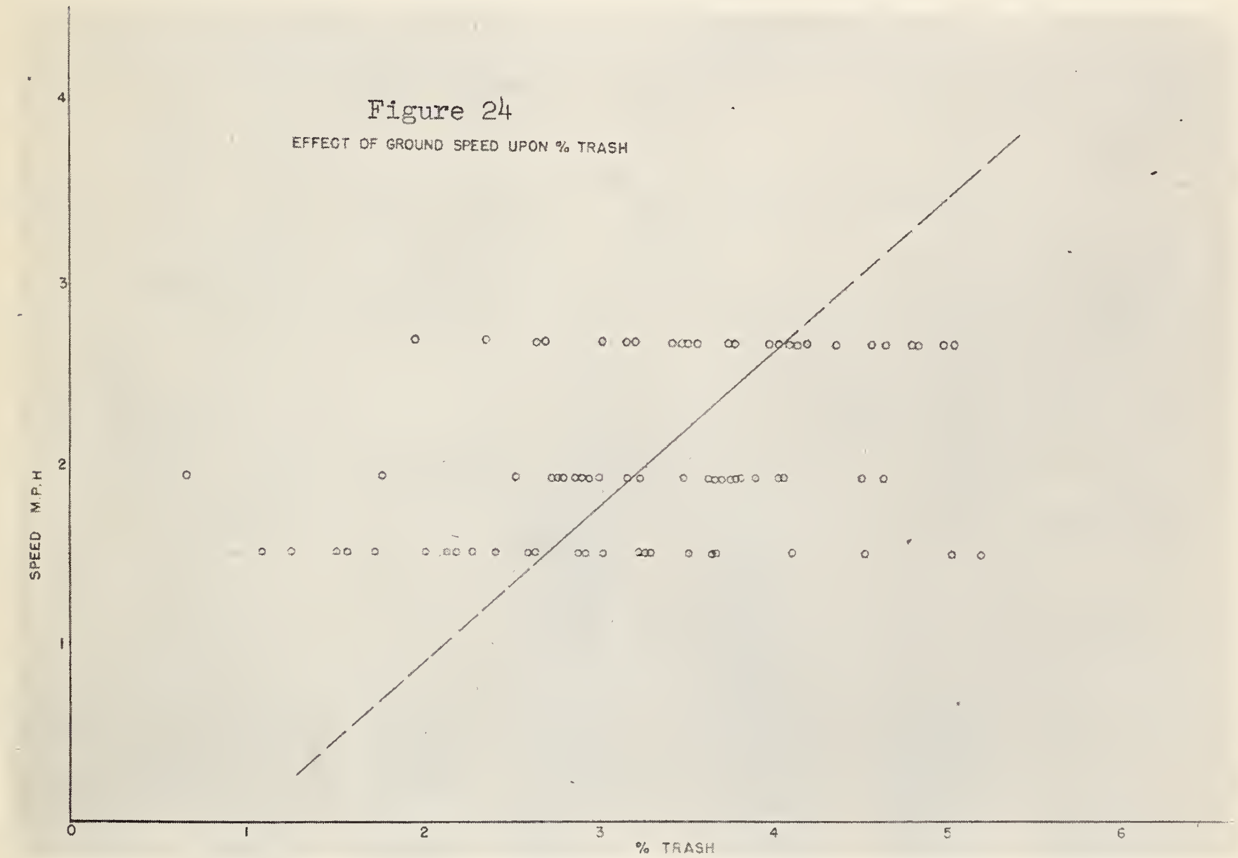
The results of these tests are as follows:

| Upper cylinder speed (rpm) | Percent trash | | | |
|---|---|---|---|---|
| | Test no. 1 C.P. 44-101* | Test no. 2 C.P. 36-105 | Test no. 3 N.Co. 310 | Tests 1 and 3 combined* |
| 446 | | 1.71 | | |
| 643 | 3.29 | 1.90 | 4.45 | 3.89 |
| 920 | 2.22 | | 3.76 | 2.99 |

* indicates significance between means at 5 percent level

In test no. 1, the reduction of percent trash is highly significant when increasing the cylinder speed from 643 to 920 r.p.m.

In test no. 2, the cylinder speed was at a lower range since the sugarcane variety C.P. 36-105 is easier to strip than C.P. 44-101 or N.Co. 310. The quantity of trash for both speeds was satisfactory for commercial operations; however, the reduction in trash was not significant for the increase in cylinder speed.




In test no. 3, the reduction in trash was not significant for the increase in cylinder speed.

The results from test no. 1 and test no. 3, combined for analysis purposes, showed a highly significant reduction in trash when the cylinder speed was increased from 643 to 920 r.p.m. The results also showed a highly significant difference as to quantity of trash between varieties.

Upper stripping cylinder speeds of 446 r.p.m. and 643 r.p.m. were used in test 2 with sugarcane variety C.P. 36-105. The trash content averaged 1.80 percent and the (r) factor of +.14 was not significant.

In test 3, upper stripping cylinder speeds of 643 r.p.m. and 920 r.p.m. were used with sugarcane variety N.Co. 310. The trash content of the 20 samples averaged 4.11 percent and the correlation coefficient (r) of .4 was significant at the .01 level. Increasing the cylinder speed decreased the trash from 4.45 to 3.76 percent.

Stripping finger life

The stripping cylinders are equipped with fingers for removing the cane leaves. The durability or useful life of these fingers is one of the major factors affecting the economical practicability of a cutter-cleaner-loader type of sugarcane harvester. Modifications in the design of a snap-in type of rubber stripping finger (fig. 25) reduced local stresses. In all, 532

Figure 25. Snap-in type rubber stripping finger illustrating the zones where failure is most frequent.

fingers were replaced while harvesting 2,296 tons of cane. This represents a useful life of approximately 9 tons of cane per finger at a cost of 0.036 cent per ton of cane. Practically all the fingers failed before they wore out, and their useful life is not considered satisfactory for commercial use. In addition to rubber, stripping fingers made of sheet rubber, tire sections, wire rope, belting, nylon, bamboo, Teflon, and steel have been laboratory and field tested to determine the most economical combination or design of material. A material is required that has sufficient flexibility to prevent bruising and shredding of the cane but at the same time is stiff enough to remove the cane leaves effectively. Strippers made of rubber and case hardened steel chain have given the best results.

Ground loss

The millable cane left in the field after harvesting is considered ground loss and in this report is expressed as a percentage of total yield. With the cutter-cleaner-loader harvesting system, keeping ground loss at a minimum is of major importance. It is not economical to hand scrap after the harvester because of the difficulty in finding the pieces of cane among the cane trash and the necessity of diverting a tractor and wagon for the scrapping operation. In the conventional harvesting method, the field can be easily scrapped during the loading operation since the tractor and wagons are already in the field, and the only additional cost is the actual labor required.

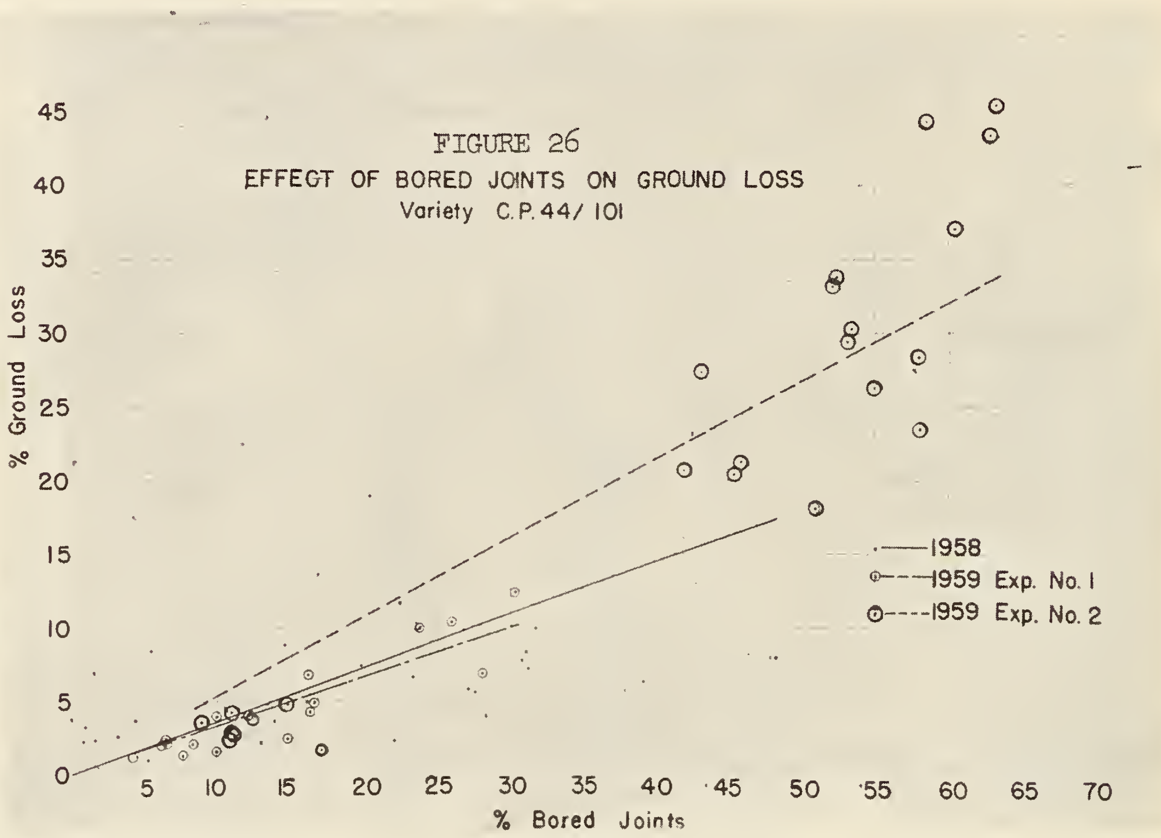
While some weaknesses in the components of the experimental harvester contribute to ground loss, field conditions and borer injury have been found to be the major factors. Badly lodged canes are a main contributor to ground loss since many of the canes are missed altogether by the gatherers or break during the gathering and conveying operation and fall to the ground. Many improvements have been made in the gathering system of the experimental harvester as well as the conventional harvesters; however, harvesting fields of lodged cane still remains a major problem. Prior to introduction of the insecticide endrin for cane borer control, ground loss caused by borer injury was greater than that resulting from lodging. Borer tunnels weaken the stalks and frequently cause them to break before or during harvest, and millable pieces are left in the field. Although chemical control of the borer has greatly reduced ground loss, borer injury still remains a major contributing factor toward ground loss for the entire industry.

To evaluate the effect of bored joints on ground loss, tests were conducted in 1958 and 1959 on sugarcane variety C.P. 44-101.[7] In these tests,

7/ Studies were conducted in cooperation with S. D. Hensley and Ralph Mathes, entomologists, Sugarcane Insect Investigations, Grain and Forage Insects Research Branch, Entomology Research Division, ARS, USDA, and Southdown Plantation.

each plot consisted of one row. Bored joints were determined prior to harvest by random sampling, and each row was harvested separately with the experimental harvester. Ground loss was determined by hand scrapping all millable pieces left on each row, including stalks missed by the gatherers, broken out by the stripper, and dropped by the loader. In all tests, borer damage was the main cause of ground loss.

The results of these tests are illustrated in figure 26. The regression




lines in the illustration are computed. In the 1958 test bored joints averaged 17.35 percent, ranging from 0 to 48.3 percent, while the ground loss averaged 6.18 percent and ranged from 0.93 to 13.53 percent. The results showed a positive correlation (r) of +.40, significant at the .02 level, between percentage of bored cane joints and ground loss. An increase from 10 to 30 percent bored joints increased the predicted ground loss from 3.6 to 10.7 percent.

Two tests were conducted in 1959. The first test consisted of randomized blocks of three treatments, replicated six times, of approximately 0.1 acre per plot. Results, illustrated in figure 26, showed a positive correlation between percentage of bored joints and ground loss (correlation coefficient (r) +.96) significant at the .01 level. Ground loss averaged 4.89 percent, ranging from 1.16 to 12.28 percent, whereas bored joints averaged 15.11 percent and ranged from 4.16 to 30.31 percent. An increase

in bored joints from 10 to 30 percent increased predicted ground loss from 3.3 to 9.75 percent. The second test consisted of 24 plots, each plot containing one row approximately 540 feet in length. The results (fig. 26) showed a positive correlation coefficient (r) +.93, significant at the .01 level, between percentage of bored joints and ground loss. An increase in bored joints from 10 to 50 percent increased predicted ground loss from 5.3 to 26.75 percent. Bored joints averaged 39.5 percent ranging from 8.7 to 63.3 percent, while ground loss averaged 21.16 percent, ranging from 1.52 to 45.45 percent.

## Summary

Maximum advantages of the cutter-cleaner-loader type of sugarcane harvester are realized in rainy weather when it is not possible to obtain a satisfactory burn with the present method of harvesting. The quantity of trash milled with the cane has averaged 1.27 to 1.61 percent less with the cutter-cleaner-loader sugarcane harvester than by the conventional method. During rainy periods the differences are greater and fluctuations from day to day are less. Trash included with the millable cane is composed mainly of cane leaves and tops, whereas with the conventional method it is composed of soil, weeds, tops, and leaves. Fresh, clean cane can be delivered to the processing plant within an hour after cutting with the experimental harvester, thereby reducing the sucrose losses caused by delayed milling and excessive trash.

Continuous operation of the experimental harvester is limited by the power of the 95 hp. engine to a maximum continuous ground speed of 1.9 m.p.h. even though field and cane conditions frequently would permit higher speeds. During the past 3 years, maximum daily capacity has ranged from 110 to 167 tons. Maximum capacity has been obtained under good field and cane conditions by close coordination of hauling operations to minimize loss of time on headlands and between wagons. The hauling capacity of the transport tractor has been approximately doubled by connecting the four-wheel wagons in trains for long hauls from the field to the mill.

Lodged cane is the main factor affecting ground loss, whether caused by wind, varietal characteristics, or the sugarcane borer. This loss must be kept to a minimum with the cutter-cleaner-loader harvesting method since it is not economical to hand scrap after the harvester because of the difficulties in finding the pieces of cane among the trash. The cutting-burning-harvesting method permits scrapping during the loading operation since the tractors and wagons are already in the field and the only additional cost is the scrappers.

Strippers made of rubber have proved effective and shown the best results in respect to durability. The present replacement cost of 0.036 cent per ton of cane for the molded rubber is not considered satisfactory for commercial use.

The rear-loading-type cutter-cleaner-loader sugarcane harvester can open fields without prior preparation or making down rows. The harvesting operations are carried on independently of the transportation system, thereby giving greater flexibility for shifting operations from field to field to meet crop and soil conditions.

## Suggestions for Future Work

Commercial acceptance of the cutter-cleaner-loader type of sugarcane harvester depends on the development of an experimental sugarcane harvester which has adequate capacity and is efficient and reliable. The major problems related to this type of harvester are (1) development of power and axle assembly of adequate strength, (2) improvement of pick-up apparatus for lodged cane, (3) improvement in the separation of trash and cane, and (4) development of wagon unloading method that will eliminate the use of cane slings.

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